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TECHNICAL DRAWINGS - C-18 & C-19 (ITEMS PARTIALLY SCANNED)

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Rev. 07/10/02

RADIAN INTERNATIONAL

A DAMES & MOORE GROUP COMPANY

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412 788 1316 Fax

20 November 1998

Mr. Michael McAteer
U.S. EPA, Region V
77 West Jackson Blvd.
HSRL-6J
Chicago, IL 60604

**Subject: Enviro-Chem Superfund Site
Preliminary Conceptual Design Report for the
Unnamed Ditch Culvert
Radian Project No. 002455.08**

Dear Mike:

Enclosed are two copies of the Preliminary Conceptual Design Report for the Unnamed Ditch Culvert.

If you have any questions or comments, please call me at 412-788-2717.

Sincerely,

for Mark J. Dowiak
Radian Design Engineering Manager

MJD:rz
Enclosure

cc: V. Epps, IDEM
N. Bernstein, Trustee
R. Ball, Environ

M:\DATA\Projects\Enviro-Chem\Correspondence\Outgoing\1998\MJD530.doc

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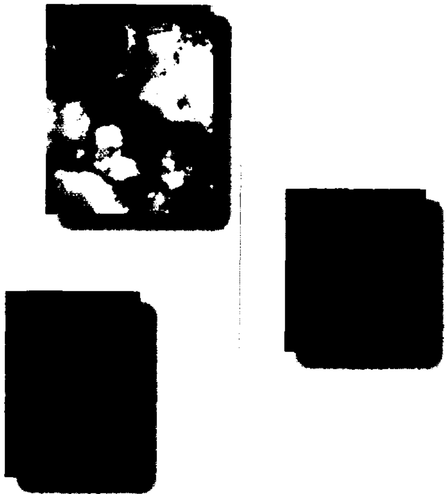

PRELIMINARY CONCEPTUAL DESIGN REPORT UNNAMED DITCH CULVERT

ENVIRO-CHEM SUPERFUND SITE ZIONSVILLE, INDIANA

PREPARED FOR:
ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION SITE TRUST

RADIAN PROJECT NUMBER 002455.08

November 1998

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PRELIMINARY CONCEPTUAL DESIGN REPORT
UNNAMED DITCH CULVERT
ENVIRO-CHEM SUPERFUND SITE
ZIONSVILLE, INDIANA

Prepared for:
Environmental Conservation and Chemical Corporation Site Trust

Prepared by:
Radian International LLC
Penn Center West
Building 3, Suite 300
Pittsburgh, Pennsylvania 15276

Radian Project No. 002455.08

November 1998

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Table of Contents

List of Tables

1.0 Introduction

This Preliminary Conceptual Design (PCD) Report has been prepared for construction of a culvert in the unnamed ditch adjacent to the Enviro-Chem Superfund Site in Zionsville, Indiana. The segment of the ditch proposed for work is between the Enviro-Chem Site and the Northside Landfill Superfund Site. The total length of the ditch in this section is about 900 feet.

The major sections of this report include:

- Design objectives
- Basis of design
- Materials list
- Calculations (Appendix)
- Design Drawings C-18 and C-19 (back pockets.)

1.1 Design Objectives

The objective of the culvert is to isolate the water in the unnamed ditch from NSL seepage & surface runoff that enters the ditch from the east, opposite the Enviro-Chem Site and upstream of the Enviro-Chem surface water monitoring point SW-2. The culvert is designed to intercept any potential bank seepage from the Enviro-Chem Site on the west side of the ditch.

The Enviro-Chem Site surface water monitoring plan includes monitoring of the unnamed ditch upstream (SW-1) and downstream (SW-2) of the site. Monitoring requirements are described in revised Exhibit A of the Consent Decree. The conveyance of the unnamed ditch flow in an enclosed culvert will not modify the location of the surface water SW-1 and SW-2 monitoring points.

2.0 Basis of Design

This section describes the database and rationale used to develop the design concept. The current site database has been developed from various site investigations.

A Remedial Investigation (RI) was conducted at the Enviro-Chem Site by CH_2MHill in 1983. To investigate the water conditions at the Enviro-Chem Site, AWD (formerly DEI and now Radian International) conducted Phase I and II Supplemental Investigations in September 1992 and January 1993, respectively. A concrete pad area subsurface investigation was conducted by AWD in November 1994, to provide additional data for evaluation of excavations in the pad area. A Supplemental Investigation of the NSL site was performed in 1992/1993 by Geraghty & Miller to obtain data necessary for the Remedial Design. The results of these investigations are found in the described reports and are not repeated here. Subsurface conditions along the unnamed ditch have been inferred from the adjoining site data. Physical conditions at the surface and shallow subsurface (upper 1 foot) have been observed from field reconnaissance.

2.1 Subsurface Conditions

The subsurface conditions in the work area were estimated from test borings advanced on either side of the unnamed ditch. The south end of the work area, adjacent to the Enviro-Chem Site southern concrete pad (now removed), is potentially the most critical area because of the presence of an artesian sand and gravel zone at depths of 10 feet below the top of the concrete pad. Typical subsurface stratigraphy overlying the artesian zone consists of a medium to stiff silty clay (till), usually with thin perched sand lenses.

A review of historical data indicates that the artesian sand zone is at a depth of about 13 feet below ground surface (~elev. 873) approximately 25 feet west of the ditch at monitoring well OW-4, near the center of the former southern concrete pad. This is the shallowest depth encountered for the sand and gravel zone west of the unnamed ditch.

The artesian zone was not encountered west of the ditch further south, between OW-4 and the NSL access road at the south end of the Enviro-Chem Site. This area consists of interbedded clayey tills and relatively thin sandy lenses to a depth of at least 20 feet. These lenses have not been found to be under artesian conditions and are apparently isolated perched water-bearing zones.

On the eastern (NSL) side of the ditch, a number of monitoring wells were installed during the Enviro-Chem RI and the NSL pre-design period. The RI wells extend from approximately 100 feet south of the NSL access road (south of the Enviro-Chem Site) at ECC-3A to the north end of the proposed culvert at ECC-2A. These wells include ECC-7A, ECC-4A and ECC-6A, all of which are 20-40 feet east of the unnamed ditch. All of these borings, except ECC-7A, encountered the sand and gravel artesian zone.

At the southern end of the work area (ECC-3A to ECC-7A), starting from approximately the north end of the Enviro-Chem Site south pad, the sand and gravel zone was found at a depth of 6-8 feet below ground surface, at elevations of approximately 868 at ECC-3A and approximately 871 at SB-75, across from the south end of the former southern concrete pad. These data indicate that, in the southern part of the culvert work area, the top of the sand and gravel zone is at an elevation of approximately 872. This equates to a depth of about 5 to 6 feet below the bottom of the unnamed ditch. Field observations indicate that approximately 6 to 12 inches of sediment are present in the ditch bottom. Therefore, at least 4 to 5 feet of silty-clay till is expected to be present between the bottom of the ditch sediment and the top of the sand and gravel zone at its highest elevation in the southern end of the work area. This till barrier is expected to be sufficient to confine the artesian zone based on uplift calculations performed for the Enviro-Chem Site south pad excavation and actual field conditions observed during that excavation. The artesian zone appears to be naturally confined adjacent to the Enviro-Chem Site. The observed base flow conditions in the unnamed ditch, approximately 50 to 100 gpm, do not support any significant artesian zone upward leakage based on the much higher artesian leakage rates encountered during the southern pad excavation.

The northern end of the work area (north of the Enviro-Chem Site south pad area) is less critical with respect to the artesian sand and gravel zone since it was found at slightly greater depths compared to the southern end of the unnamed ditch. Enviro-Chem Site wells ECC-4A, ECC-6A and ECC-2A encountered the sand and gravel zone at elevations of approximately 871 at the north end of the ditch (ECC-2A) to approximate elevation of 874 at ECC-4A near the mid-point of the work area. NSL boring GS-11, near ECC-4A, encountered the artesian zone at about elevation 873.

These elevations correspond to a sand and gravel depth of about 6 to 10 feet below the bottom of the ditch in the northern part of the work area.

2.2 Hydrologic Conditions

Existing hydrologic data on the unnamed ditch is limited to a description of the watershed area and observations of ditch flow. Typical flows observed in the summer of 1998 are 50 to 100 gpm at the discharge end of the NSL access road culvert, near the southeast corner of the Enviro-Chem Site.

Storm water flows are significant and have been observed to be up to 2 feet of flow depth. This existing NSL road culvert is 42 inch in diameter, and it has been observed to occasionally flood its inlet over the last 4 years. No flow monitoring or estimates have been performed on storm water flows in the ditch.

For design purposes, the culvert was sized based on peak flows from a 25-year, 24-hour storm. See calculations, Appendix A. The ditch watershed area was estimated at 240 acres, and includes the northern half of the NSL landfill. Peak discharge was estimated at 112.4 cfs using the SCS TR-55 method.

2.3 Culvert Alignment and Profile

The culvert shall extend along the unnamed ditch from an upstream point directly downstream of its confluence with the Enviro-Chem Site north ditch to a downstream point at the outlet of the NSL access road culvert. Total length is approximately 908 feet. See Drawing C-18.

? The NSL runoff conveyed by storm water discharge flume A (NSL-1 sampling point), the Parcel 45 diversion channel and the southern access road drainage swale will not be discharged to the culvert. The NSL runoff and the southern access road drainage will be conveyed in an open swale on the eastern edge of the culvert backfill. This east swale will discharge to a smaller culvert that extends under the NSL access road. A west swale will be constructed to collect runoff from the Enviro-Chem Site. This swale will discharge to the Parcel 45 southern diversion channel. The Parcel 45 diversion channel will discharge to a smaller culvert that extends under the NSL access road.

The culvert will be aligned to minimize sidewall soil cuts. Numerous angled fittings will be constructed to follow the current ditch curvature. See typical cross-sections on Drawing C-19.

The culvert profile is designed to be above the ditch sediment bed. Subbase material will be placed on top of the sediment to raise the culvert invert. This will avoid excavation of sediments and the potential for undercutting the confining layer for the artesian sand and gravel zone. The soft sediment subgrade will be stabilized with a geogrid to minimize settlement of the culvert subbase layer.

The culvert profile will parallel the unnamed ditch slope for most of its length, except for the downstream 149 feet of culvert. The main section of culvert will slope at 0.008 feet per feet. The downstream section will slope at 0.027 foot per foot.

2.4 Seepage Collection

The culvert is designed to collect any seepage from the western sideslope of the unnamed ditch, facing the Enviro-Chem Site. This will be accomplished by perforating the western side of the culvert and isolating this side of the culvert from the eastern sideslope (NSL Site) and the subbase with an impermeable HDPE membrane. See Drawing C-19 for the preliminary cross-section.

The HDPE membrane will be placed on the culvert subbase and wrapped around the pipe across the top of the culvert. The membrane will be anchored to the top of the western slope of the ditch. The western sideslope of the ditch will not be lined to allow the discharge of any seepage into the aggregate backfill and the culvert pipe perforations. Anti-seep collars will be placed around the culvert to prevent drainage of the aggregate backfill to the downslope end of the culvert.

3.0 Materials

The unnamed ditch culvert preliminary design is presented on Drawings C-18 and C-19. A preliminary list of major materials of construction and quantities is included on Table 3-1. No mechanical or electrical equipment items are anticipated for this project.

TABLE 3-1 Preliminary List of Construction Materials			
Item	**Unit**	**Quantity**	**Notes**
1.0 Subgrade Stabilization			
1.1 Subbase Aggregate	CY	350	IDOH No. 1 Subbase
1.2 Geotextile non-woven, min 7.7 oz.	SY	1200	
1.3 Geogrid Tensar BX 1500	SY	1200	
2.0 HDPE Membrane	SF	20000	60 mil IDOH 8 or 9
3.0 Backfill			
3.1 Select A Aggregate	CY	1000	IDOH 8 or 9
3.2 Select B Soil	CY	2000	Borrow soil (<3 in.)
4.0 Culvert Pipe			
4.1 Corrugated Stl. –60 in Alum. Stl – 14 ga.	LF	900	Contech Ultra Flow – Perforated
4.2 Seep Collars	EA	2	CMP Plate
4.3 Fittings	EA	8	11-1/4 and 22-1/2 deg. elbows
4.4 Ends	EA	3	
4.5 Manholes	EA	3	Precast concrete ring with CI Lid
5.0 Access Road Stabilization			
5.1 Geogrid	SY	~100	NSL Access Road
5.2 Subbase	CY	60	NSL Access Road
6.0 Stormwater Controls			
6.1 Swales	LF	~1600	Grass-lined
6.2 Discharge Aprons (3)	TON	200	12 inch rock riprap
6.3 Swale Culvert	LF	~100	At NSL Access Road, (2) 30-inch dia. HDPE
7.0 Vegetation	AC	~1	Grass/legume mix

REVISED REMEDIAL ACTION FINAL DESIGN

UNNAMED DITCH CULVERT

ENVIRO-CHEM SUPERFUND SITE — ZIONSVILLE, IN

LLC

CLIENT: ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION TRUST		JOB NO. 002455-08	
SCALE: 1" = 30'	DRAWING NUMBER C – 18		REV 0

AWING C-18 FOR PLAN
F CROSS SECTIONS.

LLC

REVISED REMEDIAL ACTION FINAL DESIGN UNNAMED DITCH CULVERT CROSS SECTIONS ENVIRO-CHEM SUPERFUND SITE ZIONSVILLE, IN			
CLIENT: ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION TRUST		JOB NO. 002455.08	
SCALE: AS SHOWN	DRAWING NUMBER	C-19	REV 0

APPENDIX

CALCULATIONS

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CALCULATION SHEET

CALC. NO. ____________

SIGNATURE M. Dowiak DATE 10/22/98 CHECKED Paul Alessi DATE 11/10/98

PROJECT ECC JOB NO. 002455.08

SUBJECT Unnamed Ditch Culvert SHEET 1 OF 5 SHEETS

Culvert Design - Unnamed Ditch.

REF:

1. SCS Tech. Release № 55 (TR-55), 6/86
2. USWB Tech Paper № 40 (TP-40), 5/61
3. CHOW, V.T., Open Channel Hydraulics, J. Wiley

Design Criteria

1. Open channel peak design flow for 25 YR-24 Hr rainfall event (REF. 2, Fig B-6) P = 4.5 IN/24 hr
2. Culvert Length ~ 1000 ft (See DWG. G-1)

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CALCULATION SHEET

CALC. NO. ______

SIGNATURE ______ DATE ______ CHECKED P DATE 11/10/98

PROJECT ______ JOB NO. ______

SUBJECT ECC SHEET 2 OF 5 SHEETS

1. PEAK DISCHARGE

REF: FIG. 1 - Watershed Area = 240 Ac.

1.1 Curve Number (Ref. 1)

1. SURFACE CONDITIONS
   Hydrologic Soils Group C - Soils with a slow infiltration rate and moderately fine to fine texture

2. Cover Description - Pasture, grasslands FAIR condition

$\therefore$ CN = 79 (Table 2-2c), USE 80

1.2 RUNOFF (25yr storm, Fig. 2-1)

RUNOFF = 2.5 IN

1.3 Time of Concentration (see FIG. 1)

Points:	A-B (sheet Q)	B-C (open channel)
Surface	Dense Veg.	Assume avg. V = 2 FPS
Manning 'n'	use 0.3	
Flow Length	2000 Ft.	2600 Ft
2hr-24hr (P_2 RAINFALL)	3 IN	
Elev. change	25 Ft (920-895)	20 Ft (895-875)
slope	0.0125	0.0077
Tc, hrs	3.89	$Tc = \frac{L}{3600\,V} = \frac{2600}{3600(2)} = 0.36$

A-B

$$Tc = \frac{0.007(nL)^{0.8}}{P_2^{\,0.5}\, s^{0.4}} = \frac{0.007(0.3 \times 2000)^{0.8}}{(3)^{0.5}(0.0125)^{0.4}} = 3.89 \text{ hrs.}$$

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RADIAN INTERNATIONAL™

CALCULATION SHEET

CALC. NO. ______

SIGNATURE ______ DATE ______ CHECKED P DATE 11/10/98

PROJECT ______ JOB NO. ______

SUBJECT ECC SHEET 3 OF 5 SHEETS

$\therefore$ Total $T_c = 3.89 + 0.36 = 4.25$ hrs

1.3 Peak Discharge

Type II rainfall (see Fig. B-2)

25 yr rainfall = 4.5 in (24hr)

I_a (Table 4.1) = 0.5

$I_a/P = 0.5/4.5 = 0.11$

Unit Peak Discharge, q_u = 120 csm/in
see Exhibit 4-II

Peak Discharge, $Q_p = q_u A_m R$

A_m, Drainage area in mi^2 $= \frac{A_c}{640} = \frac{240}{640} = 0.375$

$\therefore Q_p = 120 (0.375)\ 2.5 = $ 112.5 CFS

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CALCULATION SHEET

CALC. NO.

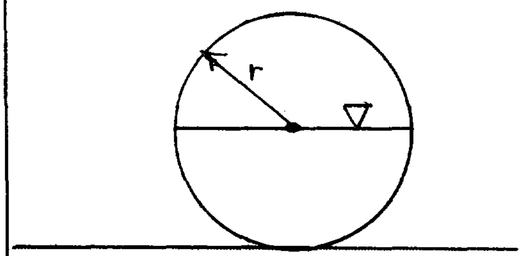
SIGNATURE DATE CHECKED P DATE 11/10/98

PROJECT JOB NO.

SUBJECT ECC SHEET 4 OF 5 SHEETS

2.0 Culvert Section

2.1 Round w/ Half Full Flow



$$A = \pi r^2/2 = 0.5\pi r^2$$

$$WP = \frac{2\pi r}{2} = \pi r$$

$$R = \frac{A}{WP} = \frac{0.5\pi r^2}{\pi r} = 0.5\,r$$

Mannings EQ'N $Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$

- Q, Peak Discharge, 112.5 CFS
- n, channel roughness
- A, Flow Area, ft^2
- R, Hydraulic radius, ft
- S, slope, ft/ft

2.2 HDPE Culvert

Re: Hancor SureLok F477 (watertight)
$n = 0.01$

$$\therefore Q = \frac{1.49}{0.01} A R^{2/3} S^{1/2}$$

$$S \cong \frac{882 - 875}{850} = 0.008$$

See DWG. G-1

$$AR^{2/3} = \frac{112.5(0.01)}{1.49(0.09)} = 8.32$$

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CALCULATION SHEET

CALC. NO. ____

SIGNATURE ____ DATE ____ CHECKED P DATE 11/10/98

PROJECT ____ JOB NO. ____

SUBJECT ECC SHEET 5 OF 5 SHEETS

Round Section radius REQ'T – HDPE

D, ft.	r, ft	A, ft^2	WP	R	$R^{2/3}$	$AR^{2/3}$	
5.0	2.5	9.8	7.85	1.25	1.16	11.36	OK
4.0	2.0	6.28	6.28	1.0	1.0	6.28	NO
4.5	2.25	7.95	7.07	1.13	1.08	8.6	OK
(3.0	1.5	3.54	4.71	0.75	0.83	2.92)	

Note: (2) - 36 IN HDPE PIPE NOT SUFFICIENT

* use 4.5 ft Dia. (54 in DIA) HDPE Pipe, or

2.3 Corrugated Steel Pipe (CSP) Culvert

Re: AISI Handbook, Table 4-10
n = 0.024 (unpaved)

$$\therefore \quad Q = \frac{1.49}{0.024} AR^{2/3} S^{1/2}$$

$$AR^{2/3} = \frac{112.5\,(0.024)}{1.49\,(0.09)} = 20.13$$

use (2) - 60" DIA CSP culverts!, or

n = 0.012 Contech HEL-COR CL

$$AR^{2/3} = \frac{112.5\,(0.012)}{1.49\,(0.09)} = 10.07$$

USE (1) 60" DIA CSP (Lined).

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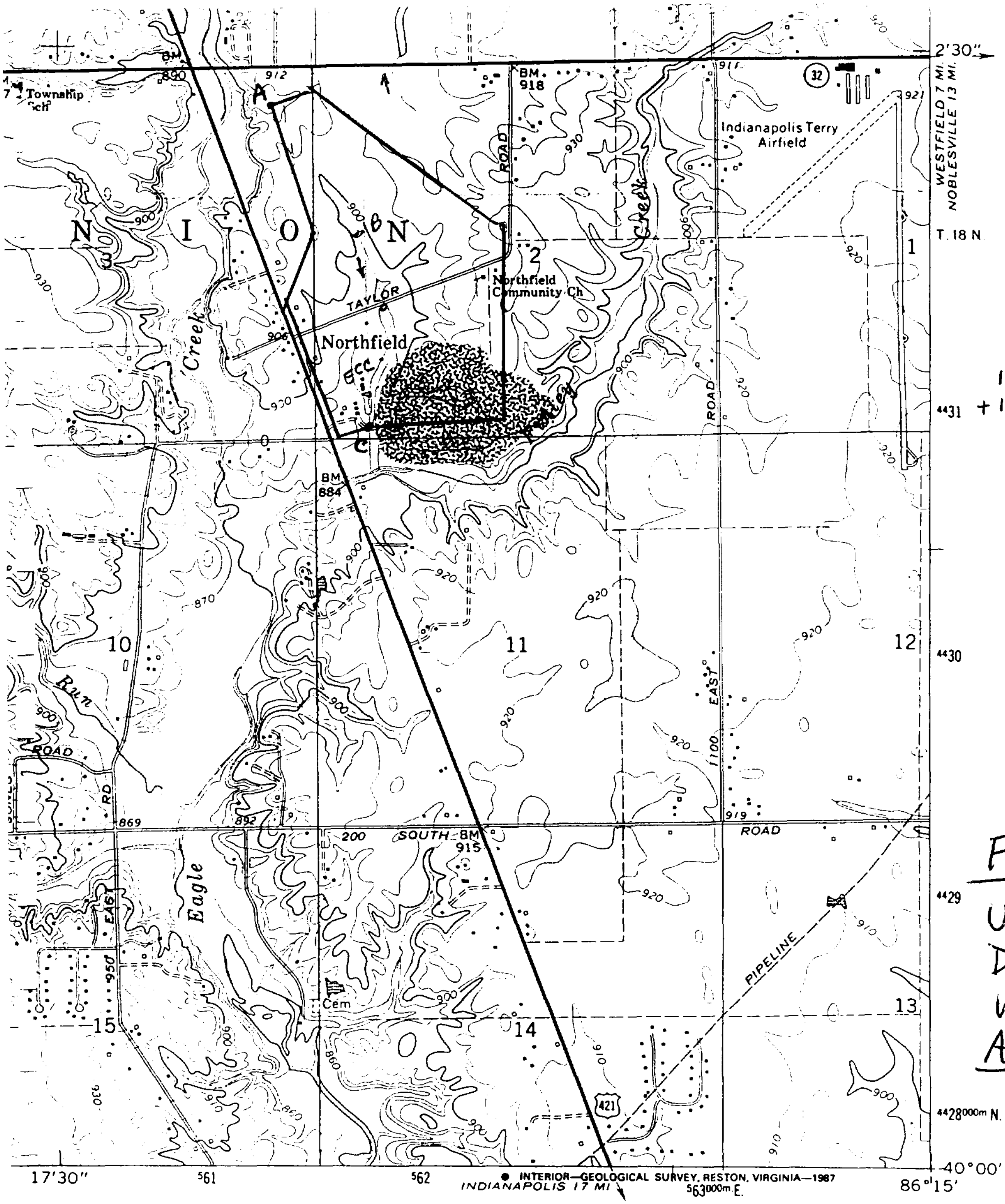

1800 x 3300 = 5.94 M
+ 1000 x 4500 = 4.5 M

10.44 M SF

= 240 AC.

Figure 1

UNNAMED Ditch watershed Area

1" = 2000'

ROAD CLASSIFICATION

Primary highway, all weather, hard surface

Light-duty road, all weather, improved surface

Unimproved road, fair or dry weather

U. S. Route

State Route

(CARMEL) 3763 I NW

QUADRANGLE LOCATION

ROSSTON, IND.
40086-A3-TF-024

1969
PHOTOREVISED 1987
DMA 3764 III SE–SERIES V851

Revisions shown in purple and woodland compiled in cooperation with State of Indiana agencies from aerial photographs taken 1981 and other sources. This information not field checked
Map edited 1987

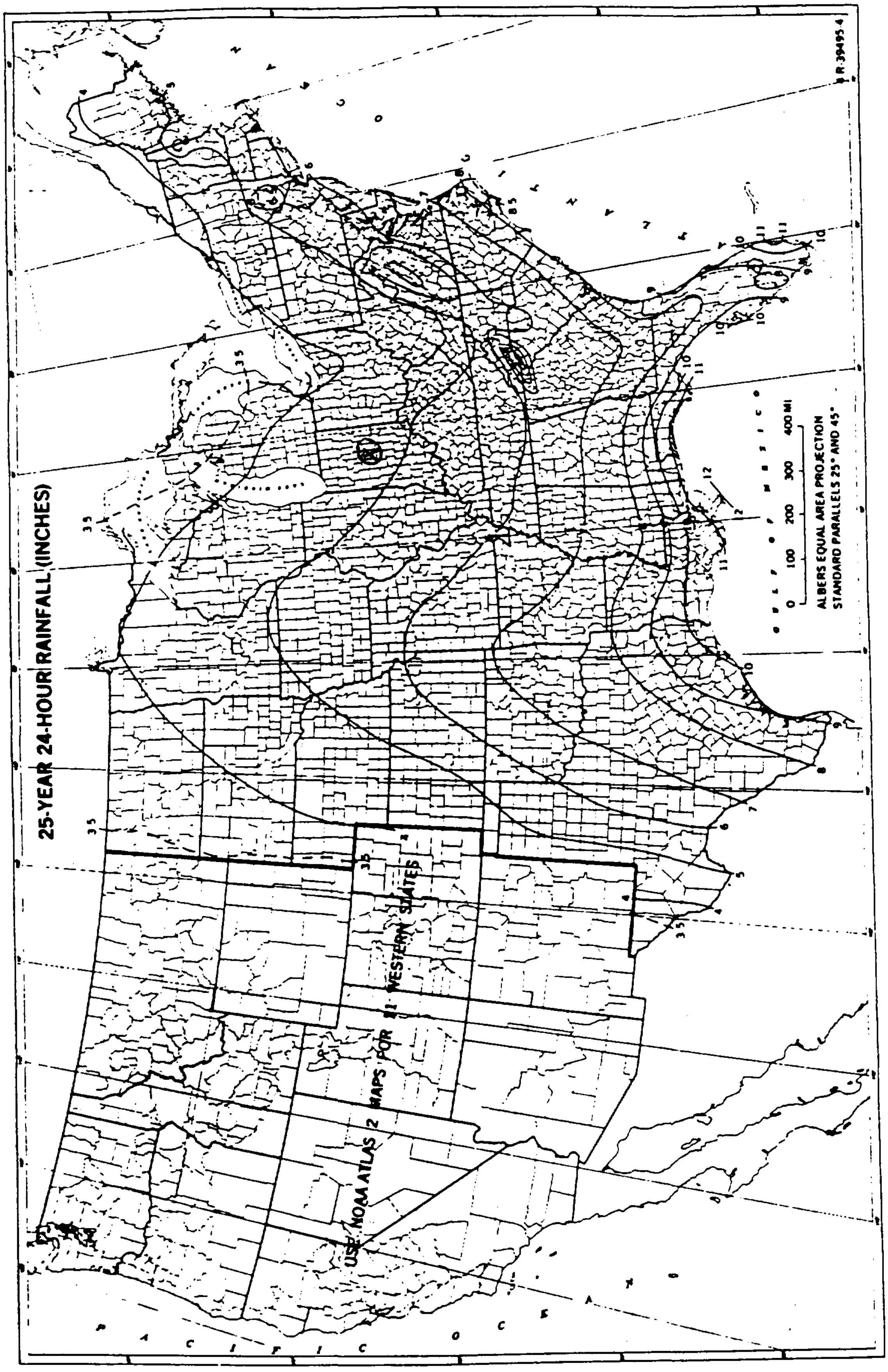

Figure B-6.--Twenty-five-year, 24-hour rainfall.

Appendix A: Hydrologic soil groups

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's, which are A, B, C, and D, are one element used in determining runoff curve numbers (see chapter 2). For the convenience of TR-55 users, exhibit A-1 lists the HSG classification of United States soils.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

In exhibit A-1, some of the listed soils have an added modifier; for example, "Abrazo, gravelly." This refers to a gravelly phase of the Abrazo series that is found in SCS soil map legends.

Disturbed soil profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred (Brakensiek and Rawls 1983):

HSG	*Soil textures*
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Drainage and group D soils

Some soils in the list are in group D because of a high water table that creates a drainage problem. Once these soils are effectively drained, they are placed in a different group. For example, Ackerman soil is classified as A/D. This indicates that the drained Ackerman soil is in group A and the undrained soil is in group D.

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Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

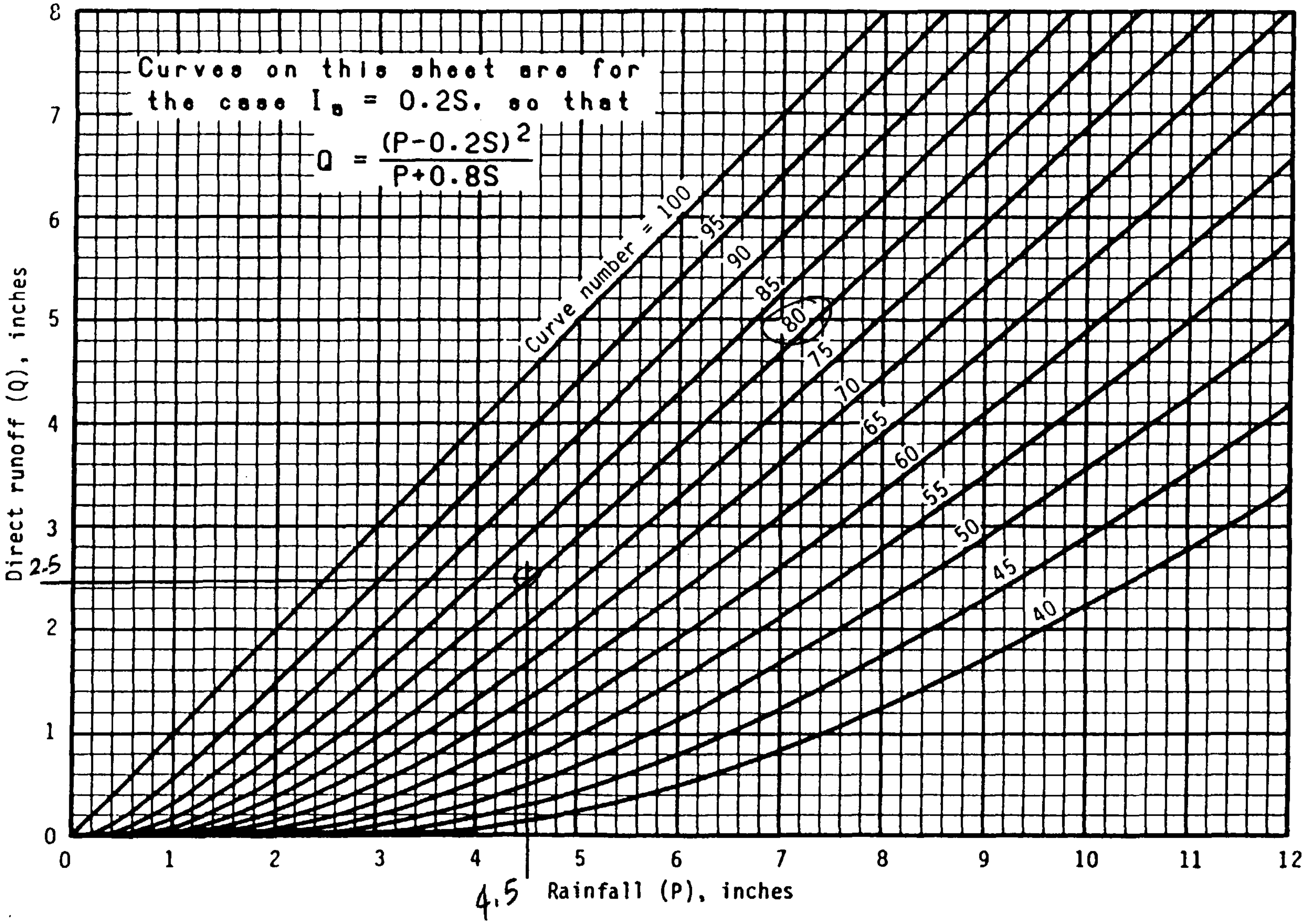


Figure 2-1.—Solution of runoff equation.

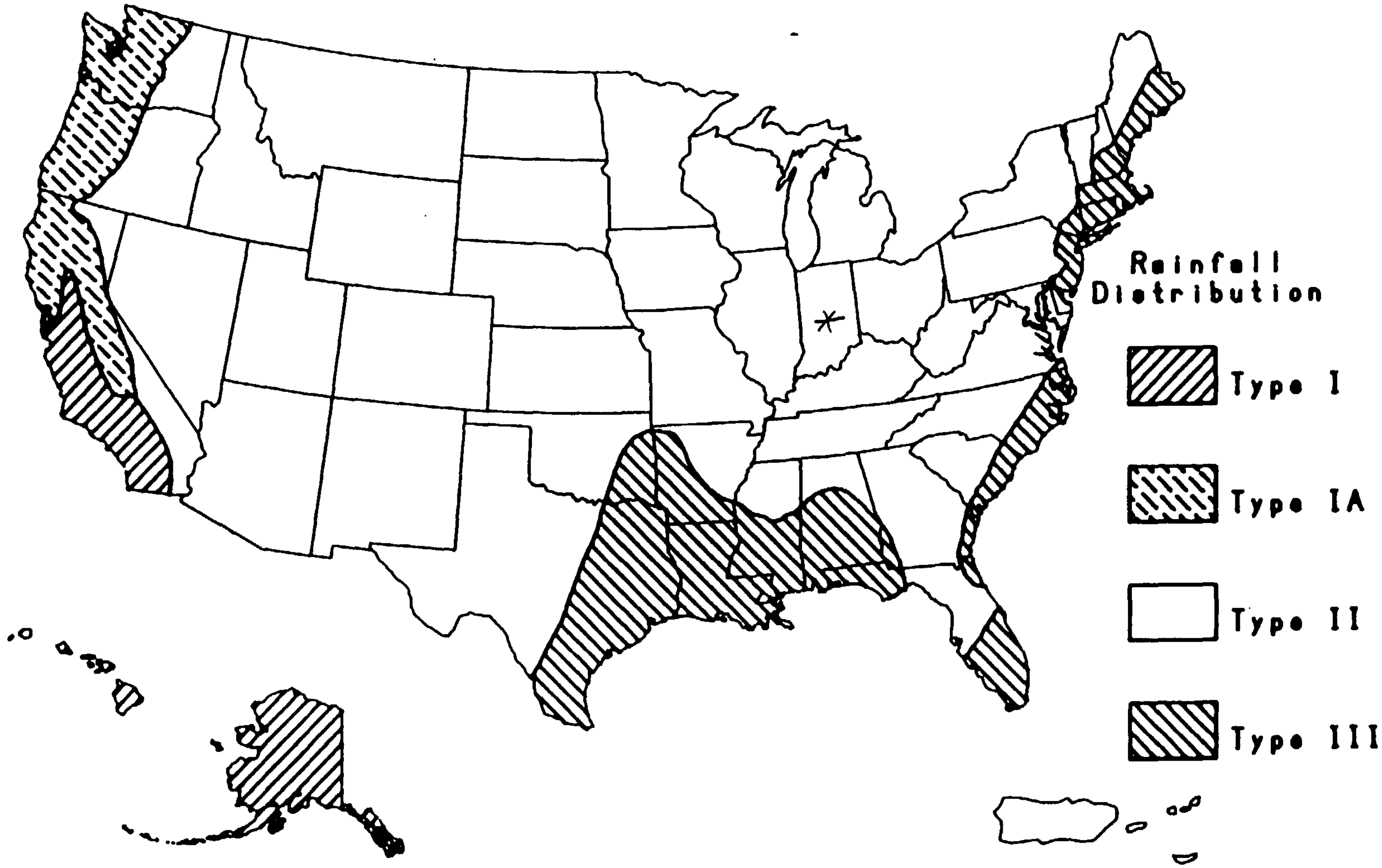


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

Chapter 4: Graphical Peak Discharge method

This chapter presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The Graphical method was developed from hydrograph analyses using TR-20, "Computer Program for Project Formulation–Hydrology" (SCS 1983). The peak discharge equation used is

$$q_p = q_u A_m Q F_p \qquad \text{[Eq. 4-1]}$$

where

q_p = peak discharge (cfs);
q_u = unit peak discharge (csm/in);
A_m = drainage area (mi^2);
Q = runoff (in); and
F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows: (1) T_c (hr), (2) drainage area (mi^2), (3) appropriate rainfall distribution (I, IA, II, or III), (4) 24-hour rainfall (in), and (5) CN. If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak discharge computation

For a selected rainfall frequency, the 24-hour rainfall (P) is obtained from appendix B or more detailed local precipitation maps. CN and total runoff (Q) for the watershed are computed according to the methods outlined in chapter 2. The CN is used to determine the initial abstraction (I_a) from table 4-1. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in exhibit 4 (4-I, 4-IA, 4-II, and 4-III) for the rainfall distribution of interest, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure 4-1 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (q_u) is obtained from exhibit 4-I, 4-IA, 4-II, or 4-III by using T_c (chapter 3), rainfall distribution type, and I_a/P ratio. The pond and swamp adjustment factor is obtained from table 4-2 (rounded to the nearest table value). Use worksheet 4 in appendix D to aid in computing the peak discharge using the Graphical method.

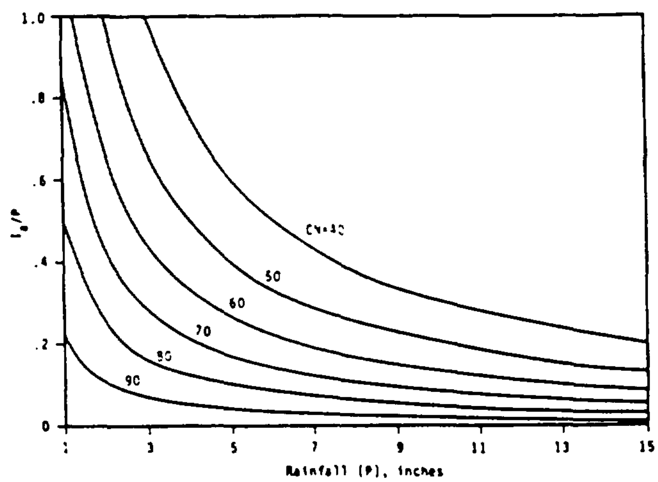
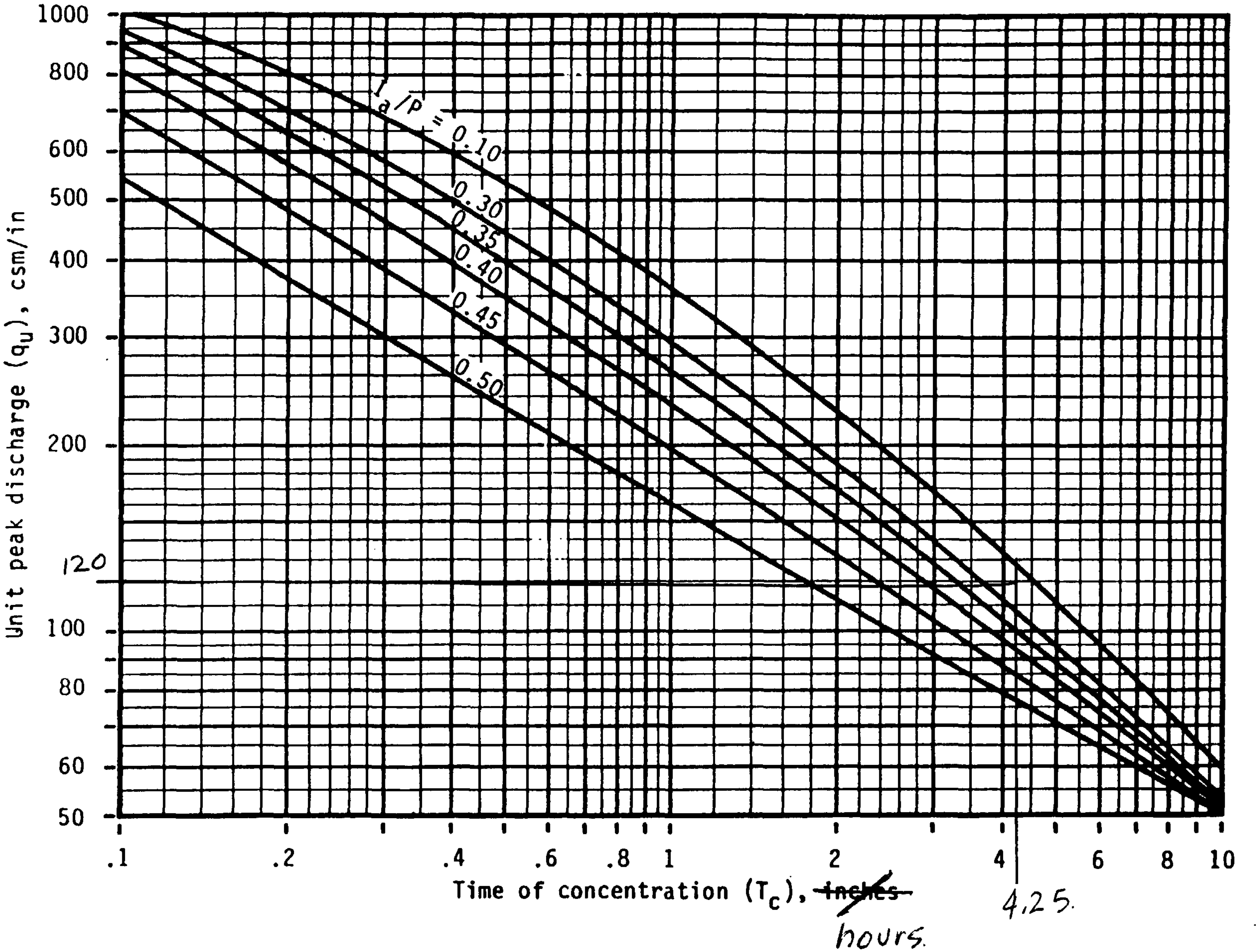


Figure 4-1.—Variation of I_a/P for P and CN.

Table 4-1.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit 4-II: Unit peak discharge (q_u) for SCS type II rainfall distribution



Re: Handbook of Steel Drainage & Highway Constr. Products, AISI, 1971

Table 4-10 Values of Coefficient of Roughness (*n*) for Standard Corrugated Steel Pipe (Manning's Formula)*

Corrugations	Annular 2⅔" x ½"	Helical						
		1½" x ¼" [11, 12]		2⅔" x ½"				
	All Diam.	8"	10"	12"	18"	24"	36"	48"
Unpaved	.024	.012	.014	.011	.014	.016	.019	.020
25% Paved	.021					.015	.017	.020
Fully Paved	.012					.012	.012	.012

Corrugations	Annular 3" x 1"	Helical—3" x 1"					
	All Diam.	36"	48"	54"	60"	66"	72"
Unpaved	.027	.021	.023	.023	.024	.025	.026
25% Paved	.023	.019	.020	.020	.021	.022	.022
Fully Paved	.012	.012	.012	.012	.012	.012	.012

(n)

*When helically corrugated steel pipe is used for air conduction, the Darcy-Weisbach formula with other values of *F* (or *n*) is used. See Table E-1, page 32.

RESEARCH ON VALUES OF *n* FOR HELICALLY CORRUGATED STEEL PIPE

Tests on helically corrugated pipe demonstrate a lower coefficient of roughness than for annularly corrugated steel pipe when there is a significant amount of helix or spiral in the pipe. For a given diameter, the greater the (angle of) helix, the less the friction factor. For a given helix, the greater the diameter, the less the friction factor.

The values in Table 4-10 are based on standard helical pipe manufactured from a 24-in. net-width strip of steel. However, the pipes tested were of a smaller diameter for a given helix angle. Further research may show even lower values when larger diameters of standard helical pipe for a given helix angle are taken into account.

Most published values of the coefficient of roughness, *n*, are based on experimental work under controlled laboratory conditions, using clear or clean water. The lines are ordinarily straight and with smooth joints. However, design values should take into account the actual construction and service conditions which vary greatly for different drainage materials. As noted on preceding pages, the friction factor for drainage structure walls is not pertinent for a large percentage of installations.

FIELD STUDIES ON STRUCTURAL PLATE PIPE[14]

Model studies by the U.S. Corps of Engineers and analyses of the same by the Federal Highway Administration have been the basis for friction factors of structural plate pipe for several years. These values shown in the 1967 edition of this Handbook, page 108, ranged from 0.0328 for 5-ft diameter pipe to 0.0302 for 15-ft pipe.

In 1968, full-scale measurements, the first of their kind, were made on a

Re: CONTECH CSP - 101

Manning's "n"

Values of Coefficient of Roughness (n)

For CONTECH Corrugated Steel Pipe (Manning's Formula)

	Annular Corrugations 2²/₃" x ½" in.	Helical* Corrugation								
		1½" x ¼" in. (11, 12)		Helical—2²/₃" x ½" in.						
	All Diameters	8 in.	10 in.	12 in.	15 in.	18 in.	24 in.	36 in.	48 in.	60 in. and Larger
Unpaved	0.024	0.012	0.014	0.011	0.012	0.013	0.015	0.018	0.020	0.021
PAVED-INVERT	0.021						0.014	0.017	0.020	0.019
SMOOTH-FLO	0.012						0.012	0.012	0.012	0.012
HEL-COR CL	0.012						0.012	0.012	0.012	0.012

	Annular 3 x 1 in.	Helical—3 x 1 in.							
			36 in.	42 in.	48 in.	54 in.	60 in.	66 in.	72 in.	78 in. and Larger
Unpaved	0.027		0.022	0.022	0.023	0.023	0.024	0.025	0.026	0.027
PAVED-INVERT	0.023		0.019	0.019	0.020	0.020	0.021	0.022	0.022	0.023
SMOOTH-FLO	0.012				0.012	0.012	0.012	0.012	0.012	0.012
HEL-COR CL	0.012					0.012	0.012	0.012	0.012	0.012

	Annular 5 x 1 in.	Helical—5 x 1 in.								
						48 in.	54 in.	60 in.	66 in.	72 in. and Larger
Unpaved	0.025					0.022	0.022	0.023	0.024	0.024
PAVED-INVERT	0.022					0.019	0.019	0.020	0.021	0.021
SMOOTH-FLO	0.012							0.012	0.012	0.012
✓ HEL-COR CL	0.012							0.012	0.012	0.012

* Tests on helically corrugated pipe demonstrate a lower coefficient of roughness than for annually corrugated steel pipe. Pipe-arches have the same roughness characteristics as their equivalent round pipes. (See Reference 4).

For additional information refer to the references listed below.

The values in the above table are based on standard helical pipe manufactured from a 24-inch net width strip of steel.

References

1. Silberman, Edward, "Effect of Helix Angle on flow in Corrugated Pipes" Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY11, Nov., 1970, pp. 2253-2263.
2. Handbook of Steel Drainage and Highway Construction Products, AISI.
3. Webster, M.J. and Metcalf, L.R., "Friction Factors in Corrugated Metal Pipe," Journal of the Hydraulics Division, ASCE, Vol. 85, No. HY9, Proc. Paper 2148, Sept., 1959, pp. 35-67.
4. J. Paul Tullis, "Friction Factor Tests on 24-Inch Helical Corrugated Pipe," Hydraulic Report No. 279, Utah State University, Utah Water Research Laboratory.

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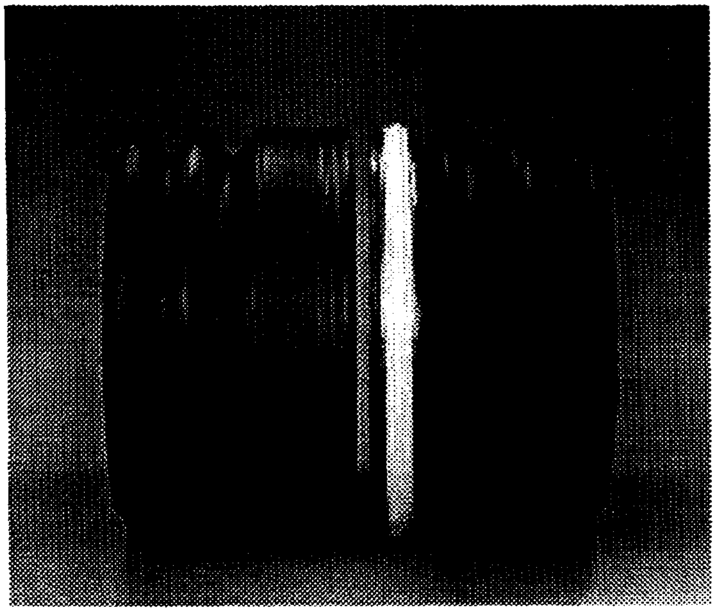
SURE-LOK F477



Sure-Lok **F477** provides all of the benefits of Sure-Lok, except with a rubber gasket

Sure-Lok **F477** is

Diameters:	4" - 60"
Length:	20-foot
Specifications:	4" - 10": AASHTO M252 12" - 48": AASHTO M294-97 54" & 60": AASHTO MP7-97
Joint Performance:	Non-rated watertight, silt-tight applications
Gasket:	Rubber, meeting ASTM F477

Hancor Sure-Lok F477 Pipe Specification

Scope

This specification describes 4- to 60-inch (100 to 1500 mm) Hancor Sure-Lok **F477** pipe for use in nonpressure drainage applications.

Pipe Requirements

Sure-Lok **F477** pipe shall have a smooth interior and annular exterior corrugations. 4- to 10-inch shall meet AASHTO M252, Type S. 12- to 48-inch (300 to 1200 mm) shall meet AASHTO M294-97, Type S. 54-60-inch (1350 and 1500 mm) shall meet AASHTO MP7-97. Manning's value for use in design shall not be less than 0.010. "n" X

Joint Performance

Pipe shall be joined with the Sure-Lok (bell-and-spigot) joint meeting AASHTO M252, AASHTO M294-97 or MP7-97. The joint shall be sil tight and non-rated watertight. Gaskets shall be made of polyisoprene meeting the requirements of ASTM F477 with the addition that the gas shall not have any visible cracking when tested according to ASTM D1 after 72 hour exposure in 50 PPHM ozone at 104 degrees Fahrenheit. Gaskets shall be installed by the pipe manufacturer and covered with a removable wrap to ensure the gasket is free from debris. A joint lubrica supplied by the manufacturer shall be used on the gasket and bell durin assembly.

Material Properties

Pipe and fitting material shall be high density polyethylene meeting AS D3350 minimum cell classification 324420C for 4-through 10-inch diameters or 335420C for 12" through 60" diameters.

Installation

Installation shall be in accordance with ASTM D2321 with the excepti that minimum cover in trafficked areas shall be one foot (0.3 m).

Pipe Dimensions

Pipe I.D., in(mm)	4 (100)	6 (150)	8 (200)	10 (250)	12 (300)	15 (375)	18 (450)	24 (600)	30 (750)	36* (900)	42* (1050)	48* (1200)	54* (1350)	(
Pipe O.D., in(mm)	4.7 (119)	6.9 (175)	9.4 (239)	11.9 (303)	14.2 (361)	17.7 (450)	21.5 (546)	28.4 (721)	36.0 (914)	41.4 (1052)	48.0 (1219)	55.0 (1397)	61.0 (1549)	(
Flare O.D., in(mm)	5.1 (129)	7.4 (188)	9.8 (249)	13.1 (333)	15.4 (391)	19.6 (498)	23.9 (607)	29.9 (759)	37.9 (963)	43.6 (1107)	50.8 (1290)	57.4 (1458)	66.0 (1676)	(
Pitch, in.(mm)	0.64 (16.2)	0.73 (18.5)	1.02 (25.9)	1.67 (43)	2.0 (51)	2.4 (61)	3.0 (76)	4.0 (102)	4.0 (102)	4.6 (117)	5.8 (147)	5.8 (147)	7.8 (198)	(
Approx. Weight. lb/ft, (N/mm)	0.44 (6.4)	1.03 (15.1)	1.6 (23.3)	2.1 (30.7)	3.3 (48.2)	4.7 (68.6)	6.2 (90.5)	10.7 (156.1)	15.6 (227.7)	18.8 (274.4)	24.7 (360.5)	29.1 (424.7)	34.6 (504.9)	(
Corrugation	Annular													
Perforations	All diameters available with or without perforations													

* Check with sales representative for availablity